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AN EARLY ANALYSIS OF ERTS-1 DATA

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An Early Analysis of ERTS-1 Data

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Introduction

ERTS-A was successfully launched to become ERTS-1 on July 23, 1972. The sensors on board were utilized to collect image data over the U.S. for the first time two days later on Tuesday, July 25. An early analysis of a data set was conducted at Purdue/LARS in order to arrive at preliminary indications as quickly as possible about the operating characteristics and potential value of this satellite as a data gathering device.

To this end a black and white image of channel 5 data together with tapes from the multispectral scanner was made available to Purdue on July 26, arriving by courier at about 11:00 P.M. Based upon a preliminary inspection of this data in image form, plans were made for four sub-projects. These involved the analysis by multispectral pattern recognition techniques of the full frame and two particular subframes and a study of the data quality as discussed below.

The frame made available for analysis was taken from the first pass of the satellite across the U.S. and was of the Red River Valley area of Texas and Oklahoma. The frame is centered on a point fifteen miles southeast of Durant, Oklahoma and approximately five miles north of the Red River.

A first look at this image suggested that the area might be rather barren, however, the analysis later showed this tc be entirely incorrect. This frame contained important and interesting examples of geology, agriculture, range land, and water resources features.

The Study Plan

As previously indicated, the data were analyzed in four sub-projects:

1. Sub-project 1 was to be a classification and a general analysis of the full frame in order to make apparent any diversity (see above).

2. A predominant and important feature in the frame is Lake Texoma and associated portions of the Red River. Accordingly, it was decided to choose for study as sub-project 2 a sub-frame incompassing this area.

3. The northeast corner of the frame contained a portion of the Ouachita Mountains, some of the oldest geologic features of the U.S. Accordingly, a sub-frame in this region was selected by geologists and foresters for analysis.

4. Finally, it was decided that it would be helpful both to the analysts at LARS and to the ERTS ground station operators to derive as much information as possible regarding various aspects of the quality of this early data. The data processing staff was to work on this task.

The results of this latter sub-project were transmitted back directly to the ERTS ground station operators. These results will not be discussed further in this report beyond the general statement that the data quality, aside from some minor and no doubt correctable flaws, appeared to be very good.

Two passes were made through the analysis of these data, first on July 27 and 28. Preliminary results of this analysis were mailed to Dr. A.B. Park and upon their receipt in Washington an additional oral report involving these materials was made by phone to Dr. John DeNoyer.

This preliminary analysis was completed without the use of ground observations or even without much general knowledge of the area. On July 30 and 31 two staff members from the Laboratory traveled to the site for ground and low-altitude aircraft observation of portions of the area covered by the frame. Based on their observations and observations and opinions expressed by local officials who accompanied them in the area, a second series of classifications was done on the full frame and the two sub-frames. Both the preliminary and the second pass results will be discussed presently.

The results of this report are contained primarily in ten images included below (Figures 1-10). Understanding and interpretation of the results will be aided by a small amount of background on how they are generated. These images are generated on a digital image display system consisting of a television-like screen upon which either data or classification results can be displayed. Facing this screen is a camera capable of exposing either polaroid or normal 35mm film. Provisions are made to interpose color filters between the black and white screen and

the photographic camera. In this way color presentations of data and results can be obtained by multiple exposure.

The display system displays approximately 600 lines down the screen face with approximately 800 addressable locations in each line. In addition, the software driving the display system is written to accept commands for displaying only every mth sample of every nth scan line of the data set for arbitrary m and n. Thus, a full ERTS frame can be displayed at lesser resolution or a smaller portion of the subframe can be displayed at full resolution. In addition, an image can be displayed such that a single resolution element in the data can be shown as a contiguous group of four (or up to 16) points when it is desirable to look in detail at a small area of a frame or small features.

In discussing the results it will be helpful to have a coordinate system mechanism to refer to individual locations in the various figures. Accordingly, we will adopt the lower left corner of the active portion of each figure as a reference point and when necessary indicate the location of a specific point in the scene by a two-tuple of numbers giving the number of millimeters to the right and the number of millimeters above this reference point, in that order.

In order to carry out the sub-projects described above, it was first helpful to derive presentations of the data in simulated color infrared photography form. The results are shown in Figures 1, 2 and 3. The remainder of the images are referred to as color-coded classification results (CCR). They are derived by classifying the data into categories, then choosing colors to associate with these categories. Typically, the number of categories is twenty or less but since the human eye cannot readily differentiate between that many colors, several of the categories are usually grouped together and presented as a single color. Next is a description of the analysis procedure, followed by a description of the two-day observation mission and a description of the results.

Analysis Procedures

When the first analysis of this data was attempted no ground information was available except that which could be deduced from comparing the data imagery to existing maps. By this process water bodies, rivers, major highways, large geologic features, and some forested areas, particularly those which occurred in drainages, could be determined. Agricultural areas and range lands could be identified from their rectangular shape in the data, but it was not possible at this point to estimate what the ground cover was. The first set of training classes was produced with the non-supervised (or clustering) classification processor by using a large sampling interval

and allowing the program to automatically pick classes. At this point the program was instructed to find 15 spectrally different classes. Because of the large sampling interval several of these classes typically contained very few points and were either deleted from the analysis or combined with what appeared to be similar classes.

The estimated identification of ground cover classes represented by the non-supervised classification classes was made using information provided by the program about each class. A table of numbers representing the separability of each class is given as part of the output of this program. Examination of these values allows the analyst to group those classes which appear similar. Another piece of information provided is the mean response of each non-supervised class within each spectral band. The ratios of the visible channels to the infrared channels provides some information as to the nature of the actual cover type. Ratio values less than one tend to indicate soils and dry vegetation while values in the vicinity of one usually represent green vegetation cover. Values much greater than one will almost invariably represent water. Tentative evaluation of cover classes can then be made from examination and comparison of the groupings and ratios provided by the non-supervised classification program. While this procedure is not rigorous it is soundly based on the spectral signature concept. It depends very heavily upon adequate band-to-band calibration.

The classes identified in this manner are necessarily broad and were typically as follows: 1) bright range land areas, 2) medium range land areas, 3) dark agricultural areas, 4) forest cover areas, 5) water. Each of these may have several subclasses. Using these estimated classes a classification was produced using the computer program. This classification was then compared with the channel 5 imagery for accuracy and several discrepancies were noted to be checked during the ground observation mission.

Following the surface observation mission it was generally possible to increase the detail of analysis both by further detailing the classes delineated by the clustering algorithm and by manually selecting points as training samples for additional classes. In the case each sub-project the details of these steps are indicated.

The Surface Observation Missions

After examining the initial analysis, several areas were designated to be examined in greater detail during the two-day surface observation mission. Points of interest were designated

in the Ouachita Mountain subframe and in the Texoma subframe. These included several areas in the forested regions of the Ouachita Mountains which had apparently been treated in some unknown manner, two extremely bright areas were also noted, and two lakes south of the Red River were suspected to be of highly different water qualities. In the Texoma subframe the primary interest was different types of water being classified within the lake, possibly associated with silting and water depth. Several bright areas were being classified primarily on the north shore of the lake. In addition, any items of interest which might be seen during the mission would be noted and photographed.

A team of two LARS staff members flew to Oklahoma City on July 30 where they were met by the Oklahoma State Soils Extension Specialist who had scheduled a light plane and pilot from the University to fly the team over the areas of interest. Thus, the ground observation team was airborne over the site on the fifth day after the data had been acquired. The team had with them the channel 5 imagery, reconstituted infrared photographs made at LARS (see Figures 1, 2, and 3), a black and white photograph of the initial classification, and a sectional air navigation chart with many of the points of interest designated, two 35mm cameras with black and white, color negative, and color positive films, and a portable tape recorder to be used for verbal comments.

The area covered by the data was entered north of the Ardmore Mountains and an eastward course was flown to the Itoka Reservoir and the Ouachita Mountain subframe. In this area the banding effect in the Ouachita Mountains (Figure 3) was observed and photographed and determined to be the result of drought stressed vegetation in combination with rock outcroppings. The cleared areas (Figure 3, top center, location 48/77) were found to be pastures which had been converted from wooded areas after aerial application of herbicides. Examples were found of areas in the process of being converted. In particular, one area which had been noted in the first classification had been sprayed this season and showed the hardwood forest to be brown to the naked eye (Blue area near top left center of Figures 3 and 9). Two areas which had been noted in the reconstituted color infrared picture could not be seen from the air (Figure 3, dark areas at locations 70/45 and 82/54). Several small bright areas were determined to be recently harvested hayfields (Figure 3, location 69/70).

Approximately one and one-half hours were spent flying over this area observing visually and photographing these various points of interest. During this time the team landed at Hugo, Oklahoma and picked up an Extension Forester who was

intimately familiar with the forest and agricultural practices of this local area. He was present in the aircraft during part of the flight over this area. After completing observations in this area, the team proceeded south to observe and photograph the two lakes south of the Red River. The flight continued westward to Lake Texoma and several points of interest were noted and photographed.

At Lake Texoma considerable time was spent in observing the visual changes in water quality and the agricultural uses of the land, particularly that on the north shore of the lake. The team then flew north to the Tishomingo Game Preserve which includes a large natural lake. It had shown differences in water classification and was surrounded by a dense, apparently natural, forested area. From this point the flight continued westward and was terminated at Ardmore, Oklahoma at the end of the day. That evening a tape recorded review of the flight was produced.

The following day the team met with a representative from the Noble Institute at Ardmore who escorted them to the area on the north shore of the lake for examination of agricultural areas and soil types. Several distinctive fields were examined and photographed on the ground for later identification in the data. Much of the land-use in this part of Oklahoma has been for range land and woodland with the intensive agriculture being cotton, grain sorghum and peanuts in sandy soils, particularly those near the lake. Several stops were made in various fields and also at several points along the north shore of the lake to examine the water quality, width of beaches, and other features near the lake. This second day of the ground observation mission was terminated in the late afternoon and the team returned to Oklahoma City by car and flew back to Lafayette that night.

Full Frame Analysis*

First Iteration. In the first iteration analysis (i.e. prior to surface observations) eleven classes were defined from the results of the clustering algorithm output. Using the procedures described above an estimate of ground cover represented in the eleven classes was made. The color-coded

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*Classification Serial Numbers: 1st Iteration, 727294701 (July 27, 1972)
2nd Iteration, 809207201 (August 9, 1972)

Run Number: 72001400
Reformatted at line interval of 2 and sample interval of 3

classification of a sizable portion of the frame is shown in Figure 4. The following table shows the colors and estimated cover types used in the color coded classification. Seven colors were used since apparently similar classes were grouped into the yellow and white color classes.

Color	Estimated Cover Class
Yellow	Bare soil and bright range lands
White	Light colored range lands
Light Blue	Medium colored range lands
Dark Blue	Dark colored range lands
Light Green	Agricultural cropland
Dark Green	Forest and woodlots
Black	Water

The features seen in this classification are the areas of water, forested areas along streams and in larger blocks in the eastern portion of the frame, and a part of the Ouachita Mountains evident as the heavily forested area in the northeast (top right) corner. The influence of man is shown by the angular fields with their north-south and east-west boundary lines. Some larger highways are discernable, but they are not too evident in this presentation of the results due to the large interval of the data points used in this set of data. Some differences in soils are shown, especially in the very bright areas on the north shore of Lake Texoma.

A puzzling discrepancy was found when several bodies of water indicated on maps were classified into one of the bright range land classes. The Atoka Reservoir was entirely in this class as were small portions of Lakes Texoma and Tishomingo. This error was the result of the large sample intervals which in turn meant that too few points were available to the clustering algorithm from these areas to adequately represent them. It also alerted the analysts to the possibility that significant differences in water quality would be seen in the data.

It was also felt that range land and pasture lands were not separated as distinctly as they might be.

Second Iteration. With the knowledge gained from the ground information mission and resource people contacted in Oklahoma, a second iteration of the analysis was produced.

The original classes were retained and additional classes were added, based on the ground information, to correct the known errors and improve the separation of classes. Training samples were taken from the Atoka Reservoir, Lakes Texoma and

Tishomingo, and several pasture areas visited by the ground information team. The new set of classes thus was a combination of automatically selected classes from the clustering algorithm and hand-picked classes defined by the analyst.

The color coded classification using the second set of classes is shown in Figure 5. As in the first classification some similar classes were combined and therefore the 17 classes are presented with 11 colors. The colors and their corresponding estimated cover types are listed as follows:

Color	Estimated Cover Class
Yellow, Tan, Brown, Light Green	Range lands and pastures
White, Light Gray	Sandy or Bare Soils, Light Vegetation, Agricultural fields with sparse canopy
Dark Green	Forest and woodlots
Dark Blue, Blue Gray, Aqua	Water (3 subclasses)
Dark Purple	Atoka Reservoir

The second classification shows more classes and detail than could be seen in the first. The Atoka Reservoir (only southern tip shown, Figure 5, location 87/78) is now not only correctly classified but is shown to be a class of water distinct from all others in the picture. The Atoka Reservoir is of relatively uniform depth of about 20 to 30 feet over much of its area and it is a source of water for Oklahoma City. Three other water classes appear in the various lakes. Patterns of yellow, tan and brown pasture and range land are seen forming generally broad east-west lines separated by valleys with green, light gray, and white areas. A large brown area in the Ouachita Mountains (top right corner) is a pasture area which has been converted from the surrounding forest. The boundary lines here are very distinct as they are are around the large yellow range land near the top left (Figure 5, location 25/71).

Highways are seen again as faint white lines. For example, at the extreme left Interstate Highway 35 enters the picture about half way from the top and continues to the bottom. It passes through the west (left) edge of Ardmore, Oklahoma (Figure 5, location 03/33) which appears as a white, almost circular area near the left edge and slightly below the center point. The Red River is a sinuous, light blue line entering Lake Texoma from the West and continuing from the Texoma Dam

(North-South straight line near bottom center; Figure 5, location 62/6) to the right edge of the picture.

Figure 5 covers slightly less than 2/3 of the total frame and represents an area of approximately 75 by 50 statute miles in size. Because of the large amount of data present in this image, it is difficult to fully evaluate and discuss the results. Our objective in this study, to obtain a preliminary indication of the utility of ERTS-1 data, will be more fully approached by a more detailed look at the smaller subframe areas.

Texoma Reservoir Subframe Analysis*

First Iteration. Thirteen classes were defined by the clustering algorithm in the first analysis of this data. The cover types represented by these classes were estimated as before and a classification was produced. The color coded classification is shown in Figure 6. Grouping of similar classes was done as before and a set of six colors was used to represent the broad cover types.

Color	Estimated Cover Type
White	Bare or lightly covered soils, light colored range land
Yellow	Medium range lands
Light Green	Agricultural crops, dark range land
Dark Green	Forest
Red	Muddy or shallow water
Light Blue	Clear, deep water

Although more detail was observed in the field structure of the range and pasture lands it was still suspected that even more could be produced. Forested areas appeared too extensive when the classification was compared to data imagery. Two water classes were defined in this classification and they were associated with shallow or muddy water in Lakes Texoma and Tishomingo. In Lake Texoma the "shallow/muddy" class was located at the head of the lake, at the heads of each small inlet, that this class could be subdivided to make the distinction between shallow clear water and muddy, silted water.

There are instances of surprising detail in this classification as, for example, in the case of two highway bridges visible across Lake Texoma and some north-south roads visible in the green forest class. These features cannot be as wide as the resolution of the scanner; they are visible because of high contrast in the response between the features and their background thus creating enough change in the data point to cause it to be placed in a class different from that of the background.

Second Iteration. As in the full frame classification the information gathered during the ground mission was used to define additional classes which were added to those selected by the automatic clustering algorithm. Classes were added to improve separation in water quality, agricultural crops and range land. The second classification contains 18 classes which are subdivided into 4 broad land use categories. The color coded classification is shown in two photographs. Figure 7 shows about half of the subframe (approximately 27 by 25 statute miles) and Figure 8 is an enlargement of the west end of Lake Texoma (approximate 14 by 12 statute miles). The colors and estimated cover classes for both Figure 7 and Figure 8 are listed below.

Color	Estimated Cover Type
Blue Gray, Light Blue, Aqua Medium Blue, Dark Blue	Water (5 classes)
White	Sandy and Light bare soil, Light colored dry vegetation, agricultural fields with low crop coverage
Red	Agricultural fields with high coverage
Light Green	Forest, sparse canopy
Dark Green	Forest, more dense canopy

Features of particular interest in these photographs are the various classes of water which appear in Lake Texoma and Tishomingo. The west (left) end of Lake Texoma shows the delta where the Red River enters the lake as a white hook-shaped feature which is the dry portion of the delta. The aqua blue adjacent to the dry delta is a portion of the delta which is barely covered with water. It is less than three feet in depth in much of the delta area and is visibly muddy to the boundary of the light and medium blue. There is a very narrow band of blue-gray between the aqua and light blue which may be associated with the edge of the delta. The medium blue and dark blue represent relatively clear water with the dark blue tending to be in the deeper areas. This association is not always true and may have been effected by surface wave action. There is a recurring gradation in color in the small inlets from dark blue, medium blue to light blue which must be related to decreasing depth in these locations.

Lake Tishomingo (Figure 7, location 75/77) was classified into three classes, aqua, light blue and blue-gray, all indicating shallow and muddy or silty water similar to that in the west end of Lake Texoma. Three small lakes may be seen in the light blue class between Lake Tishomingo and Lake Texoma. The yellow line through the green area immediately below Lake Tishomingo is a

narrow stream through a very heavily forested area. The stream width is well below the resolution of the scanner and therefore could not be classified into a water class. The large rectangular red area at top right (Figure 8, location 87/76) is a field of cotton and grain sorghum which was visited on the ground. In addition to occurrence for cases of cropland this red class may be seen occurring frequently near green forested areas particularly near the head of Lake Texoma. In this latter case it probably represents a misclassification of ground cover similar to cropland, possibly heavy weeds and grassland. The white areas near the lake, and in particular just north of the bridge (Figure 8), were found to be fields of light, sandy soils usually containing peanuts which in most cases showed a very low ground cover, usually between 20 and 50%. It is unlikely that ground areas of this type could be detected as agricultural vegetation at this stage in the growing season due to the very bright soil background. In this area there were also many pastures containing flowering weeds and dry grasses which presented a very bright target. Many of these pastures showed evidence of overgrazing. This exposes greater amounts of soil, appearing brighter in the data.

The yellow, light brown, and light tan fields represent the many varied pasture and grassland cover types which occurred in this area. Ground information was not adequate to define specific cover types in these classes. The dark and light green areas represent woodlands which typically occur in drainage areas. The white classes are seen far more frequently on the north or Oklahoma side of the lake. This is due to the occurrence of deep sands north of the Red River in contrast to relatively shallow loams on the Texas side. Peanuts are grown on the Texas side but the fields are smaller (10-15 acres) compared to 80-500 acres on the Oklahoma side. The large fields provide a bright target since the crop cover was very low at the time data was collected.

Ouachita Mountains Subframe Analysis*

First Iteration. Preliminary classification was carried out using the clustering technique for the entire Ouachita Mountains area in which 15 spectral classes were designated. Detailed analysis of the statistics from this data indicated that several of these spectral classes should be combined, since they were not significantly different. This was carried out, resulting in a set of 10 spectral classes which were used to make the preliminary classification. This classification showed a number of interesting

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*Classification Serial Number: 1st Iteration, 0727206801 (July 27, 1972)
2nd Iteration, 0908206908 (Sept. 8, 1972)

Run Number: 72001402
Maximum Resolution, Line and sample interval of 1

features being spectrally defined and classified. The CCR is shown in Figure 9. The assignment of colors is as follows:

Color Code	Cover Type
White	Interstate 75 and other highly reflecting objects.
Yellow	Soil areas.
Green	Non-dense vegetation, predominant on the top of the plateau.
Blue	Areas having low infrared response and caused by the activities of man. These areas do not exhibit the spectral characteristics of green vegetation although they appear to be located in an area which normally would have been forested.
Magneta and Red	Forested areas. The red includes areas of high infrared response and magneta predominantly areas of relatively low response in the infrared channels, perhaps due to topographic influences.

An extremely straight line which was later verified to be a powerline location showed up very clearly in the classification results, as did Interstate 75. (Of course, these were also evident on the individual wavelength bands of ERTS imagery.) Forested areas in the mountains appeared to be well-classified although there was some question concerning the interrelationships between spectral response caused by topographic differences and spectral response variations caused by differences in the vegetative cover.

Several large blocks of land had a very low spectral response in the infrared channels of the MSS data. The borders of these areas appeared to be very straight, with some rectangular corners, indicating that they were not natural features (note Figure 3, location 06/70 and 80/55). Another area on top of the plateau (location 49/76) had similar straight boundary lines with corner features, again indicating human activity, but this area did not have such low infrared response. The initial classification showed that both of these features were identified spectrally and mapped as blue on the classification results. Some other similar areas which had not been previously noted were also identified as having the same spectral characteristics.

Reservoirs in this region demonstrated at least two spectral characteristics which could not be explained in interpretation of the imagery. The differences in spectral characteristics were particularly striking in Channels 4 and 5 (visible wavelengths) of the MSS data, where one reservoir had a relatively high response while the other reservoir had a relatively low response.

In general, the preliminary classification allowed spectral definition of a number of interesting and perhaps significant features, but the significance of these results could not be accurately judged because of a lack of information concerning the actual cover types in these areas. A number of rather specific questions arose concerning the cause of variations in spectral response and the cover type present in several of these locations. A number of these unexplained features were given to the surface observation team as specific target points on which to obtain information regarding the causes of the particular responses which had been observed. General information concerning the cover types and condition was also requested.

Second Iteration. Following the return of the surface observation team, we found that the visual and photographic data which had been collected by them proved to be of great interest and of considerable value in interpreting the results of our data analysis sequence. A number of oblique aerial photos of certain areas indicated that the areas having the straight boundaries and rectangular corner features were indeed caused by human activity, but there was a number of different factors involved. In the area on top of the plateau (Figure 9, location 60/55) a clearing operation had taken place in which the forest cover had been removed and wind-rowed, allowing native grasses to dominate the scene. This was one type of range land improvement project. Rectangular boundaries observed in these areas on the oblique photography corresponded very well to the ERTS imagery. In another region (Figure 9, location 06/46) the rectangular boundaries were caused by aerial spray operations of the forest cover. This spray (2,4,5-T) had caused the trees to die, resulting in the tree crowns having a medium brown tone to the eye, and a very low response in the infrared channels of the ERTS imagery. This was another type of range improvement program.

The surface observation team also determined that the powerline area had a grass cover over most of the right-of-way. A third area in the imagery (Figure 9, location 80/55) which had an extremely low spectral response in Channels 6 and 7 could not be verified by the surface observation team because of a lack of visual difference in the area being investigated. They flew around the region indicated on the ERTS imagery for some time but were not able at low altitude to identify any apparent differences between this area and the surrounding materials that had a more normal response. Correspondence with the local Extension Forester has indicated that this area was sprayed with 2,4,5-T last year but that the spray application was not adequate to completely kill the trees. Consequently, this year the vegetation has developed its normal green appearance (to the eye), but it is still under a serious stress condition, resulting in a distinct decrease in infrared reflectance. This situation explains the difficulty that the surface observation team had in locating that particular area on the ground.

Following the return of the surface observation team, a more detailed analysis sequence was undertaken for this area. Particular attention was paid to the mapping of the different forest cover areas and the water resources in this region. A number of small areas were designated for use in clustering analysis and from these it was determined that at least 20 significant spectral categories were present in the data. A set of training samples were developed and the Ouachita Mountain subframe was again classified, using the maximum likelihood algorithm. Further refinements on this classification are still being carried out. It appears that all 20 of the spectral response patterns are of significance for their potential differentiation of the various features in this imagery. However, there do not appear to be 20 categories of cover types which are significant. One of the most difficult tasks in this analysis involves defining the techniques used to group the various spectral categories into the surface features of significance.

The final classification results are shown in Figure 10, which has the following color code scheme:

Color Code	Cover Type
Dark Green	Forested areas
Light Green	Forested areas having high response due to topographic position.
Black	Forested areas having low infrared response due to stress conditions and topographic position.
Dark Red	Forest area that has been ~~spready~~ SPRAYED with 2,4,5-T for a range control project.
Magneta Red	Forested areas of low infrared response most of which have presumably been ~~spready~~ SPRAYED with 2,4,5-T.
White	River Area--water and surrounding vegetation.
Very Pale Yellow	Highly reflecting objects including I-75, limestone outcrops, and scattered points of highly reflective material (particularly soils).
Yellow & Brown	Agricultural areas having large amount of soil exposed.
Blue	Range land

The final classification results show the power line very distinctly, and I-75 has a fairly distinct spectral characteristic.

The area where the forest cover had been sprayed also were defined as a distinct spectral category (Note Figure 10, location 02/60). The number of spectral classes were grouped into the various range land areas, including one having a distinct spectral response on top of the plateau (Figure 10, location 42/65).

One of the most interesting features defined by the final classification involved the distinct banding effect related to the geologic structure of the Ouachita Mountains. Surface observations and aerial photos of this area indicated that the spectral differences causing this banding were the result of a number of different features. In some cases limestone outcroppings caused a very distinct spectral response (Figure 10, location 32/37) and in other cases the banding was caused by a combination of topography and vegetation effects. Distinct differences in slope and aspect were observable and these seem to be closely related to differences in vegetative density. The surface observation team also indicated that very distinct, observable moisture stress in the forest cover along some of these geologic structures was observed. At the present time, the relationships between spectral response, moisture stress conditions, vegetative density, and the characteristics of the underlying geologic features and their moisture holding capacities are not known, but we do believe that the results here indicate that the vegetation is reflecting accurately the underlying geologic and soil characteristics of this area.

Differences in the water quality were cited by local contact personnel as the cause for the spectral differences observed in the reservoirs in this area. These water quality differences were not particularly obvious to the eye from light aircraft, but did show up distinctly on the ERTS imagery. At least three distinct spectral responses have been observed in the reservoirs in this area with a fourth spectral category representing small rivers and their surrounding cover types. A small river north of Antlers, Oklahoma (Figure 10, location 61/51) showed up clearly in the classification results, although it is believed that this spectral class represents a combination of water and other vegetation and soils materials rather than only the water. This belief is based upon the analysis of the spectral characteristics of the data for that particular class of material as well as knowledge of the size of the river and resolution of the scanner.

Summary and Conclusion

Results of the analysis of this area thus far indicate a great deal of potential in the analysis and interpretation of this ERTS imagery. The analysis discussed in this report, which is only a preliminary one, concentrated on the geologic, forest, range, cropland and water resources of the area. It appears that more than 20 significant spectral classes are present in the data, but

a fewer number of categories of informational value are present.

One of the most difficult problems at the present state of the remote sensing art appears to be the refinement of a straight-forward technique to relate the spectral classes present to the significant categories of interest defined by the users. The work here required analysis of ERTS data in an area where local conditions were not known by the analysts. The analysis sequence tested involved (1) preliminary analysis based solely upon the spectral characteristics of the data, followed by (2) a surface observation mission to obtain detailed information from local resource people, as well as visual observations and oblique color photography of particular points of interest in the test site area. This appears to provide an extremely efficient technique for obtaining particularly meaningful surface observation data. Following such a procedure allows one to concentrate on particular points of interest in the entire ERTS frame and thereby makes the surface observation data obtained particularly meaningful. The final step (3) involved more detailed and refined analysis sequences which can then be pursued in a much more definitive manner. The development of a procedure for utilizing a clustering algorithm in an analysis technique involving small geographic areas for initial clustering also appears to have great potential for further analysis of large scale areas using ERTS data.

We believe this particular analysis sequence has been significant from the standpoint of demonstrating a fast turn-around (and therefore low-cost) analysis capability, a capability to show the complexity of natural resource and man-made features that can be identified and the potential of mapping these using ERTS data, and in the development of better analysis techniques for further ERTS work. Whether CCR's of the type produced here can indeed become accurate and useful land-use maps of an area remains to be seen but promise has clearly been indicated. Multi-temporal imagery should provide even greater promise.

Acknowledgments

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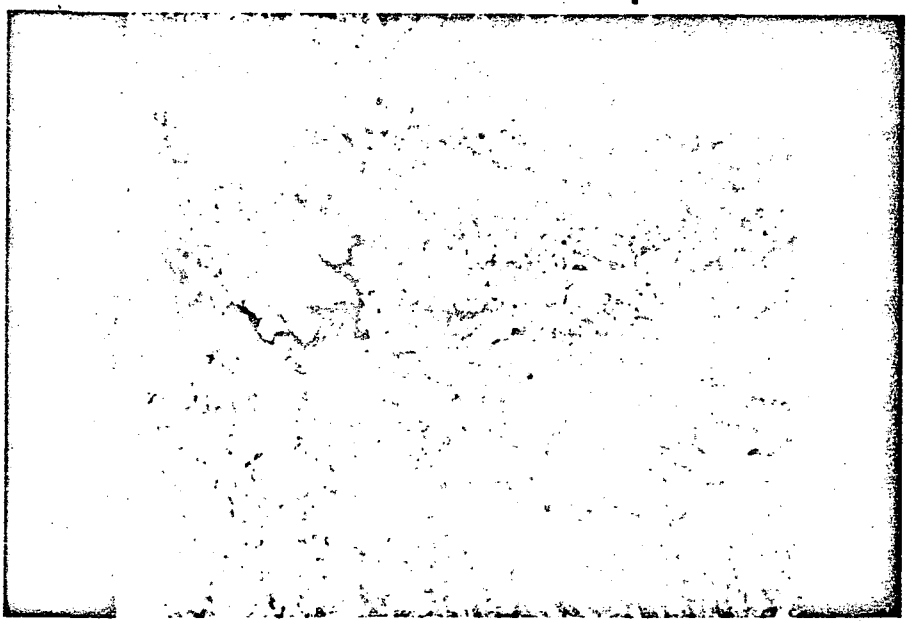

Figure 1

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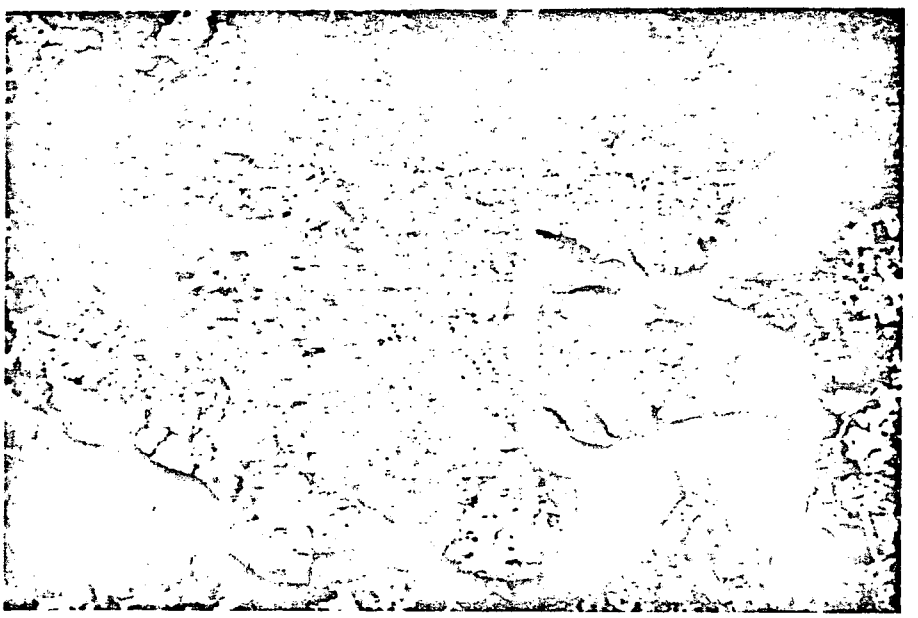
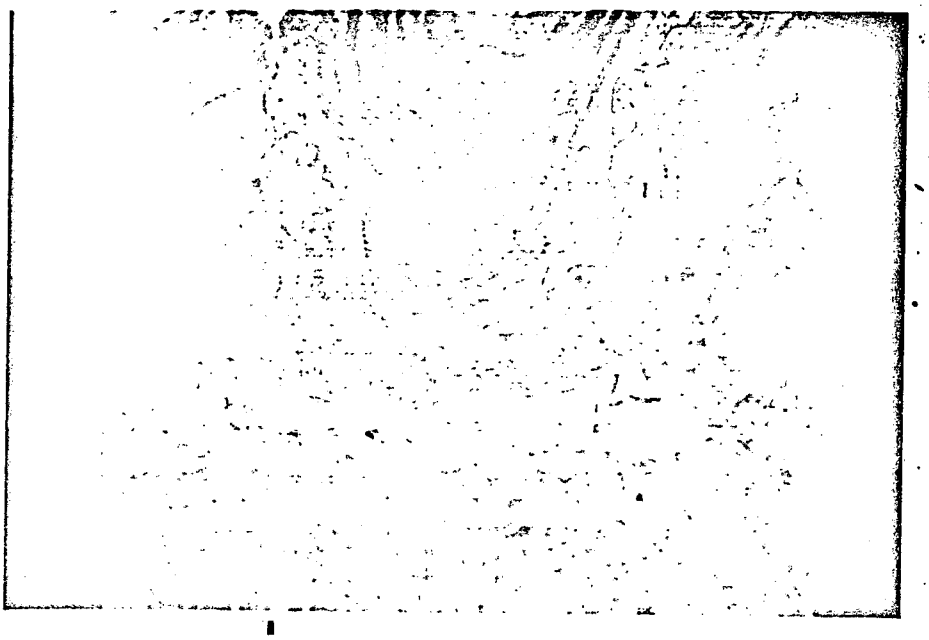


Figure 2



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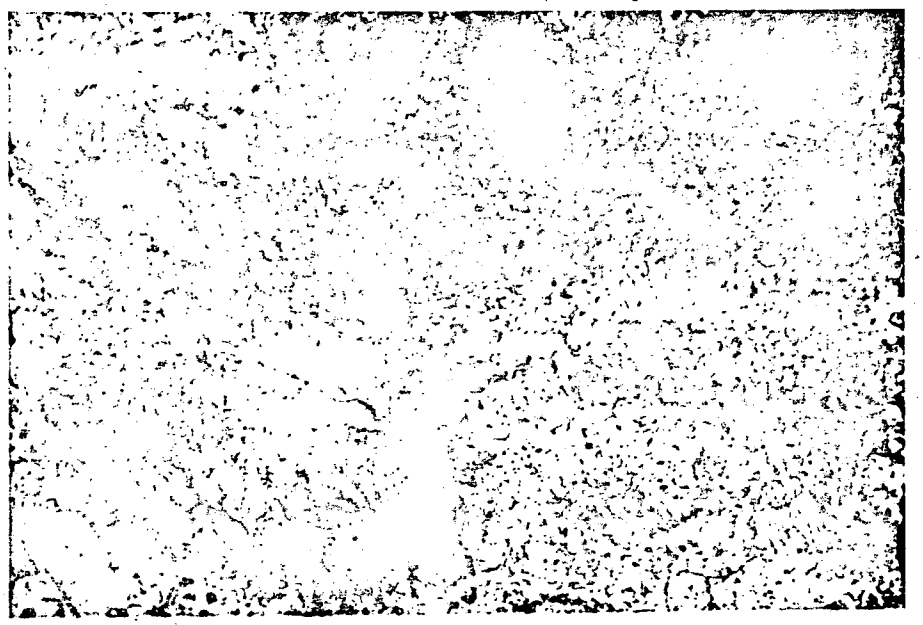

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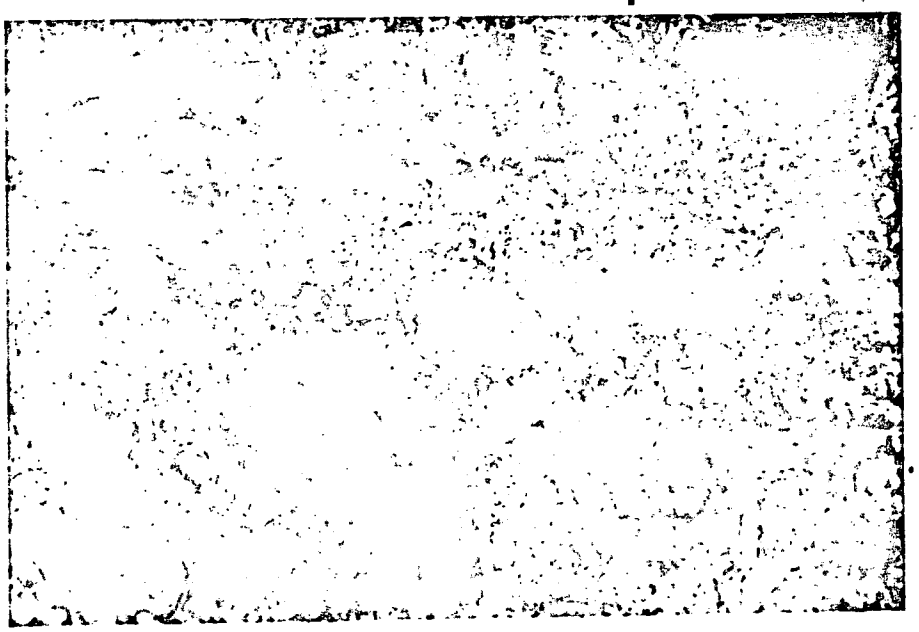

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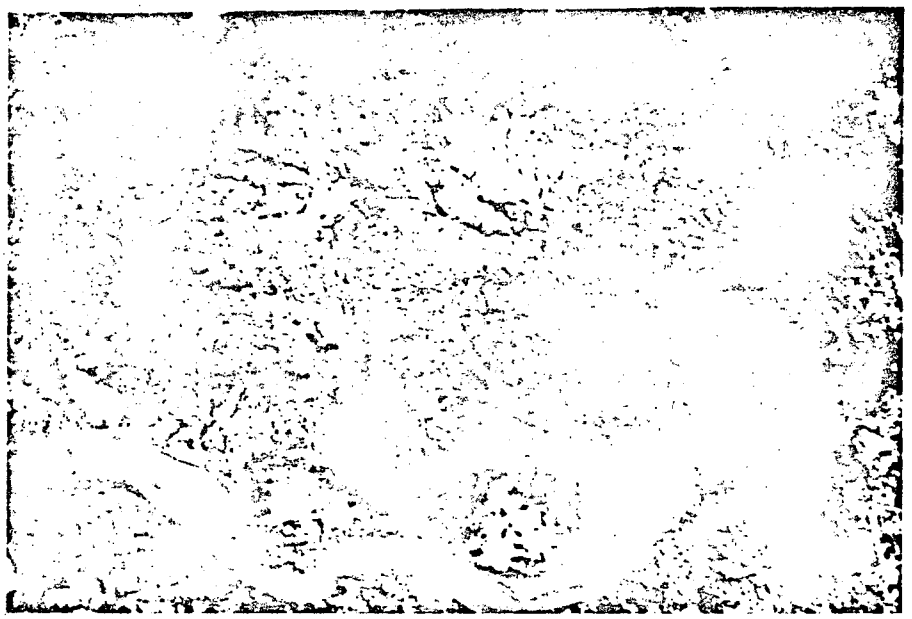

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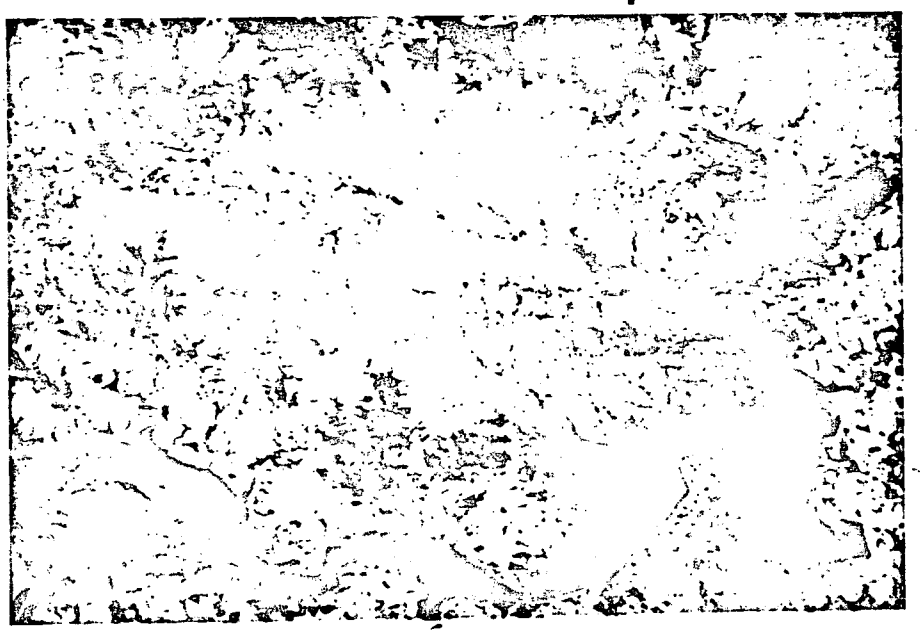

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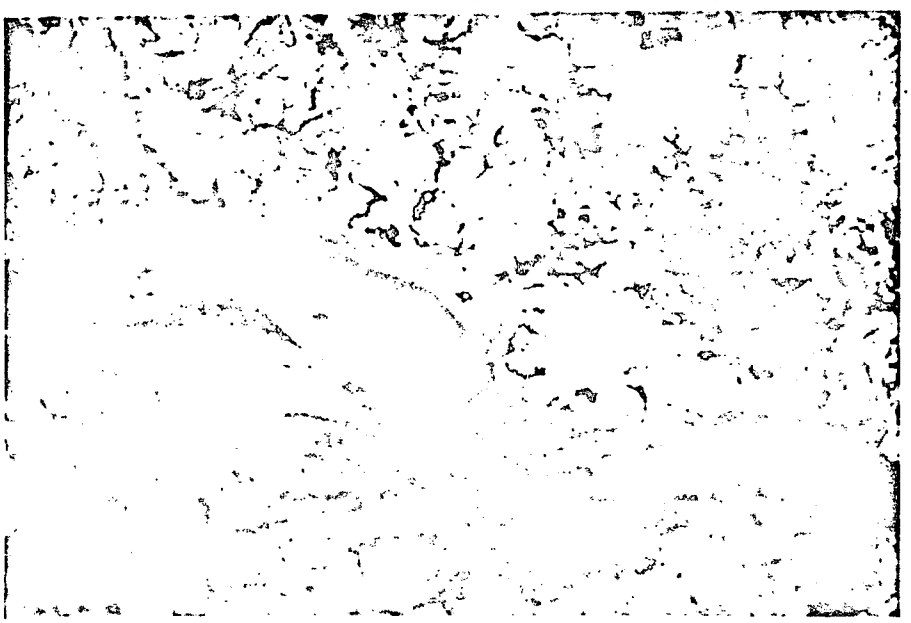
Figure 7



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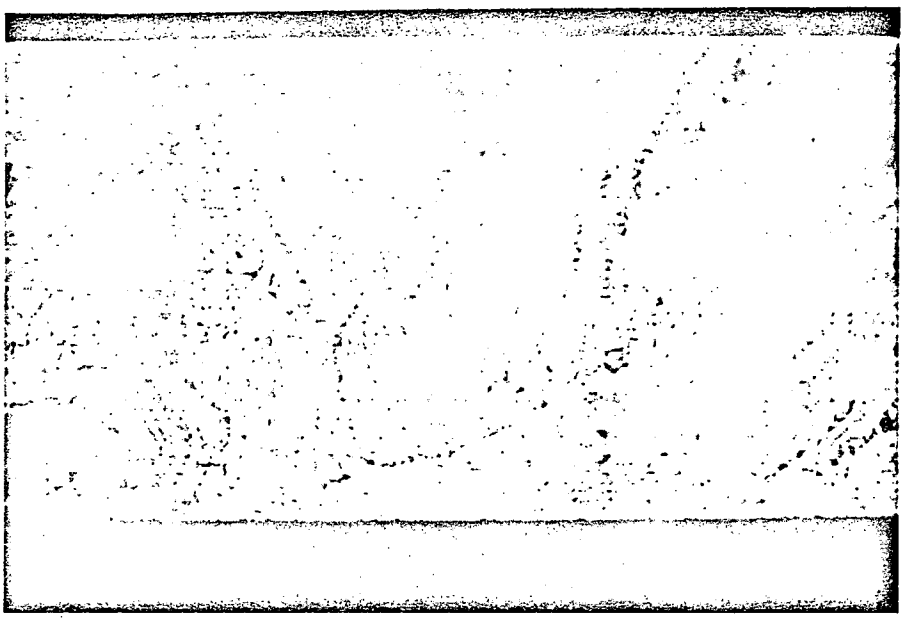

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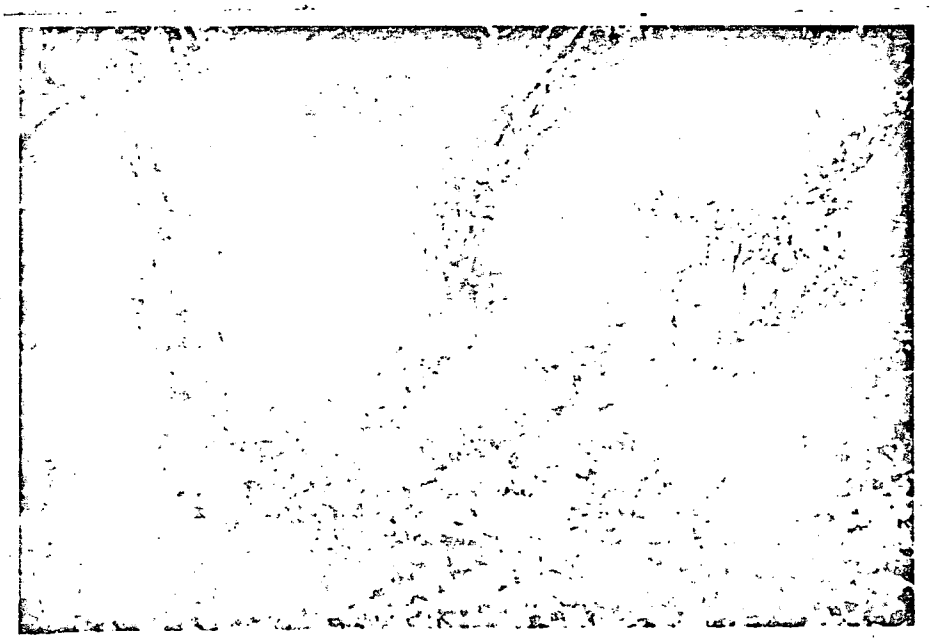

Figure 10